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FINE TOOTH MILLING TREATMENT OF RUTTED ASPHALTIC CONCRETE PAVEMENTS

FINAL REPORT

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16. Abstract The Portland cement concrete (PCC) pavement on Interstate I-94 between the Minnesota State Line and Osseo, Wisconsin was resurfaced with asphaltic concrete (AC) between 1983 and 1990. The section completed between 1983 and 1986 showed early signs of distress with rutting in the driving lane wheel paths. As a result, a milling technique for rut removal was used to rehabilitate this stretch of highway. The intended benefits were to improve the ride and texture of the surface and enhance safety by removing areas of potential water ponding. Different milling techniques were evaluated to identify the most effective method of achieving the desired results. Fine tooth milling was finally selected as the best available milling method for this stretch of highway. Rut, noise and ride or International Roughness Index (IRI) were measured and anaylzed, while the Pavement Distress Index (PDI) values were extracted from WisDOT historical data. Measured rut values on the milled surfaces indicated minor rutting up to the third year after milling. The rutting progressively deteriorated up to the sixth year when the highway was fine tooth milled a second time. PDI slightly decreased after milling, but in less than one year became similar to the results obtained prior to milling. As a result, the district responsible for this stretch of highway recommended that subsequent fine tooth milling include adequate crack treatment. Ride as measured by IRI did not show any significant differences between pre- and post-rut milling. Noise measurements indicated that the fine tooth milling does not effect significantly the interior and exterior average noise levels. The noise measuring equipment used however, may not have isolated the discrete tone referred to as "whine" which is objectionable to auditory senses. Hence, the noise measurement results may be inconclusive. Cost analysis, based on WisDOT bid tabulations, and using the equivalent uniform annual cost method showed that resurfacing would cost about fourteen times more than milling without crack treatment and ten times more with crack treatment. Available results, therefore indicate that fine tooth milling is a viable rehabilitation technique for PCC pavements with AC overlay which has experienced premature rutting. It is a recommended treatment for use on this type of pavement when the desired service life is six years or less, however, caution and judgement should be exercised on using this technique on older, more "brittle" pavements.

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FINE TOOTH MILLING TREATMENT OF RUTTED ASPHALTIC CONCRETE PAVEMENTS

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FINE TOOTH MILLING TREATMENT OF RUTTED ASPHALTIC CONCRETE PAVEMENTS

INTRODUCTION

Approximately 130 centerline miles (208 centerline kilometers) of Portland Cement Concrete (PCC) pavement on I-94, between the Minnesota State Line and Osseo Wisconsin, was resurfaced with asphaltic concrete (AC) pavement. This resurfacing operation was carried out between 1983 and 1990 by the Wisconsin Department of Transportation (WisDOT). The projects completed between 1983 and 1986, showed early signs of distress with rutting in the driving lane wheel paths. Rut depths in excess of 0.5 inches (12 mm) were observed in some stretches by 1989. As a result of this early distress, the District responsible for maintaining this stretch of highway decided to experiment with fine tooth milling for rut removal as a rehabilitation technique. The intended benefit was to improve the ride and texture of the existing rutted surface and enhance safety by removing areas of potential water ponding. This was expected to improve the quality of the pavement and probably extend the life for 5 - 7 years.

Initially, an information search was conducted to identify different milling techniques and determine the most effective method of achieving the desired results. Results obtained on milling techniques tested using different milling machines were documented in an interim report [1] . Based on these results, fine tooth milling was selected as the best available milling method for rut removal on this highway. The first segment of the milling project began at the I-94 / STH 25 Interchange in Dunn County to the Dunn / Eau Claire County line, a second segment started from Dunn / Eau Claire County line to the I-94 / USH 12 interchange while a third segment stretched from the I-94 / USH 53 Interchange to East of the Eau Claire / Trempealeau County Line. Segments 2 and 3 are in Eau Claire County. Fine tooth rut milling was carried out on the driving lane only on both the East and West Bound directions in 1991. Approximately 66-lane miles (106 lane kilometers) of the pavement were fine tooth milled.

A Wertgen front loading milling machine with a 12.5 foot (3.8 m) drum was used. The drum had approximately three times the number of teeth of a conventional milling machine. On the average, the milling generated about 200 tons (203 Mg) of removable material per lane mile (1.6 lane km) and was able to mill approximately 4 miles (6.4 km) in a 12 hour work day. The driving lane and a 2.5 foot (0.76 m) section of the shoulder were milled. Milling started at the bottom of the left wheel rut and maintained a minimum constant slope of 0.015 ft/ft (0.015 m/m) to the right shoulder. With the milling operation extending 2.5 feet (0.76 m) to the shoulder in one pass, milling of the rest of the shoulder to achieve positive drainage was not necessary.

This rehabilitation technique offered a quick and easy construction operation with minimal traffic disruption. In addition, milling can take place in almost any weather condition, except the coldest winter months, hence the technique can offer a long rehabilitation season for this type of pavement. However, it was noted that a significant amount of money ($80,000) was required for modifying the milling machine before the milling operation could commence. Further details on the milling machine and the milling operation are available in the interim report(1).

TEST SECTIONS AND PARAMETERS MEASURED

Test sections were selected from the east bound lane. Test sections were approximately one mile (1.6 km) each. Rut and noise values were measured on these test sections. The rut depth was taken every 0.10 mile (0.16 km), while the noise was measured as detailed in the 1991 noise report (2). International Roughness Index (IRI) was also measured on the test sections while the Pavement Distress Index (PDI) values, were extracted from historical data maintained by the Pavements Section in the Department.

Rutting was the primary concern in this investigation. Rut measurements were taken prior to the milling operation and immediately after the completion of the project, and yearly thereafter, except in 1995. Previous milling projects often displayed increased tire noise, causing the motorist to complain. As a result, internal and external noise were also measured.

RESULTS AND ANALYSIS

Rut

Rutting, a longitudinal depression in the wheel paths, can effect the safety of the traveling public, and thus, was the primary concern intended to be addressed by this milling operation. Rut values obtained from 1990 to 1997 are shown in Table 1. These values are the average rut measurements of each wheel path (Left Wheel Path (LWP) and Right Wheel Path (RWP)).

In a given test period, the rut values obtained on the Right Wheel Part (RWP) were generally lower than those on the Left Wheel Path (LWP). However both wheel paths exhibited a progressive increase in rut depth with age (Table 1).

Rutting could be considered insignificant for the first two years after milling, with a severity of zero (Severity Level 0 = rutting 0 to 0.25 inch (6.25 mm))[3]. However, it became significant, though minor (Severity Level 1 = 0.25 inch (6.25 mm) to 0.50 inch (12.5 mm)) from the third year and progressively deteriorated through the end of the investigation. In 1997, after six years in service, the rut milled surface exhibited rut values almost as high as those obtained in 1991 prior to the milling operation. The pavement condition had deteriorated to the point that the district personnel found rutting sufficiently significant, and in the summer of 1997 this stretch of highway was fine tooth milled for a second time.

Distress and Ride

As mentioned earlier, WisDOT uses PDI as an indication of the level of pavement distress. PDI measures the extent and severity of all the distress types and combines them into one index. The index values range from 0 to 100, with 0 as the best possible condition. The International Roughness Index (IRI) is used as a measure of ride experienced by the road users. IRI ranges from zero (perfectly smooth) to over five (very rough). The PDI and IRI values are presented in Table 2.

The table shows that the PDI slightly decreased after the pavement was fine tooth milled. However, this reduction lasted for less than one year after milling. By the second year, PDI values were similar to those obtained prior to milling and progressively increased up to the end of the investigation. Based on this experience, the district responsible for this stretch of highway, recommended that any future fine tooth milling project include adequate longitudinal and transverse crack treatment.

IRI results do not indicate any significant difference before and after the fine tooth rut milling. Also there is no significant change in the IRI with age. This implies that fine tooth rut milling did not improve the ride quality of a pavement that already rode good, even though it was effective in eliminating the rutting in the pavement.

Noise Study

A Metrosonics DB-308 digital sound meter mounted in a 1990 Chevrolet Celebrity was used for measuring and recording the interior noise levels. The parameter measured was the sound intensity in decibels (dB). The sound meter microphone was attached to the passenger headrest, and the vehicle driven at 60 miles per hour (mph) (100 km/h) over each test section and two sound level readings taken. This process was repeated at a higher speed of 65 mph (110km/h). Noise measurements were taken immediately before and after the pavement was milled, then repeated at approximately two weeks and again at three months after milling. Both peak and average interior sound levels were recorded.

Exterior sound levels were measured by mounting the Metrosonics DB-308 digital sound meter on a tripod. The tripod was then positioned off the roadway approximately 21 feet (6.4 m) from the centerline at each of the first four monitoring locations. At the fifth location, the tripod was positioned 64 feet (19.5 m) from the centerline. Noise level measurements were taken as single vehicles passed the test sections. The size or classification of each vehicle passing through the test section was noted. Before milling, sound readings were taken only on the vehicles traveling on the lane to be milled. Likewise post-milling readings were also limited to the vehicles traveling on the milled lane only. Sound measurements were not taken when more than one vehicle was passing through the test section at close proximity to each other. A detailed description of the noise measurement technique is available in the noise report(2).

The following observations were made from the report(2) :

Interior noise results show that there was a noticeable difference in the sound pitch between the pre-milled and post-milled conditions for a period up to about two weeks after milling, while the change in loudness (dB) appears to be insignificant. However, results taken after three months did not indicate any discernible pitch change. At that time, it was noticed that motorists were not moving over to the non-milled lane, which has been the usual practice in previous milling projects, indicating that the change in frequency was not significantly objectionable.

Exterior dBA levels did not indicate any significant difference between the pre-milled and post-milled condition. Also, a subjective exterior noise assessment showed that no significant difference existed between milled and non-milled lanes (driving and passing lanes respectively) as the vehicles passed through the test sections.

The report(2) concluded that the fine tooth rut milling method for asphaltic concrete pavement does not significantly increase either the exterior or the interior noise levels. As a result, noise related problems do not appear to be a significant factor that would affect a decision on the selection of fine tooth rut milling as a feasible alternative for AC pavement maintenance.

This conclusion was based on the available information and technology at the time of testing. In a recent noise study(4) on a variety of asphaltic concrete (AC) and Portland cement concrete (PCC) pavements, a type 2900 Larson-Davis two-channel real time acoustical analyzer (RTA) was used for the noise measurements. This RTA could measure both American National Standards Institute's (ANSI) preferred octave band and 1/3 octave band frequencies. This study(4) identified and isolated a discrete tone objectionable to auditory senses, which is often referred to as “whine” as the major discomfort to the motorist. This whine may not have been detected by the noise testing equipment used in this stretch of highway. As a result, the conclusion that fine tooth rut milling for asphaltic concrete pavement does not significantly increase either the exterior or the interior noise levels in the pavement may be inconclusive, and may require further study.

However, experts interviewed in fine tooth rut milling believe any that noise problems associated with this technique can be minimized, if the following precautions are taken:

- The machine used for grinding and planing should be equipped with a moldboard capable of planing raised surface irregularities or unusual ridges. The moldboard should be located immediately behind the mandrel.
- The moldboard should be straight, true and free of excessive nicks or wear and should be replaced as necessary to uniformly produce the required surface texture.
- The forward speed of the milling machine should not exceed 35ft/min (10.7 m/min). Best results are obtained at 25ft/min (7.6 m/min).
- A uniform constant downward pressure determined for a particular pavement should be applied to the moldboard. This pressure should be applied with enough force to produce the required surface texture, but not high enough to break up the pavement.

COST ANALYSIS

The fine tooth asphaltic pavement milling was paid for at a contract unit price of $0.39 per square yard ($0.47/m^2). The unit price was full payment for milling, sweeping and clearing; for disposal of surface materials; and for all labor, tools, equipment and incidentals. The amount was paid only once, regardless of the number of passes required to achieve acceptable results. In Dunn County, the milled material was reused on county roads as surface binder. The county paid for the cost of hauling the millings. In Eau Claire County, the contractor hauled the millings from the job site and sold them for approximately $4.00 per ton ($4.4/Mg) to a local village for use as a street base and surface course. The total cost of milling was $182,403.93 for 8,467,701 square yards (390,998 m^2) of pavement, representing a cost of $2,989.65 per lane mile (1.6 lane km). This project did not include longitudinal and transverse crack treatments. However experience gained has shown that future rut milling projects should include such treatments. This addition is estimated to increase the future costs of such projects by approximately $5000.00 per lane mile (1.6 lane km).

A cost analysis based on WisDOT bid tabulations was carried out on a three inch (7.6 cm) AC overlay (resurfacing) project and also on the fine tooth rut milled project. The cost analysis showed that the resurfacing project (3 inch (7.6 cm) AC overlay) with an estimated life of 13 years has an equivalent uniform annual cost (EUAC)[*] of approximately $8000.00 per lane mile (1.6 lane km). The fine tooth rut milling with estimated life of 6 years had EUAC of $590 per lane km (lane mile) without crack filling and routing. When crack filled and routed, the EUAC is $790 per lane mile (1.6 lane km). This implies that a resurfacing project would cost about fourteen times more than a milling project without crack filling and routing. If the cost of treating the cracks is included, the resurfacing project is estimated to cost about ten times more. This method, therefore, appears to be highly cost effective as a short term rehabilitation technique for this type of roadway. This would be particularly useful in situations where there are many competing lane miles for limited resources. It would also alleviate an immediate concern while a more permanent solution is planned.

However, fine tooth milling is discouraged where the AC surface layer is = 1.25 inches (31 mm). Also, it is not applicable on paved shoulder thicknesses of = 2.00 inches (50 mm). Thicknesses less than those indicated may not withstand the desired moldboard downward pressure.

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[*] EUAC is defined as the total cost per year including the maintenance cost, over the life of the project

OBSERVATIONS / CONCLUSIONS

Rutting, which was the primary distress being treated by this project, was reduced to an insignificant depth after milling, thereby increasing the safety for the roadway users. This rut depth remained constant for the first two years after milling. Rut depth, however, progressively increased and became of minor significance during the third through sixth year, when the district fine tooth milled the highway segment a second time.

The pavement distress index (PDI) reduced slightly after milling, but progressively increased throughout the period of investigation. Based on the experience gained in this project, the district managing this stretch of highway recommended that any future fine tooth milling project include adequate longitudinal and transverse crack treatment prior to milling.

The international roughness index (IRI) was not significantly effected by the milling operation, either immediately after milling or during subsequent years. This implies that the ride quality measured by IRI was not significantly affected by milling.

Interior noise results indicated a difference in the sound pitch between the immediate pre-milled and post-milled conditions up to the first two weeks after milling, but the change in loudness was found insignificant. After three months, a discernible pitch change was not indicated. However, the equipment used for this test may not have detected the “whine” in the pavement which causes the most noise discomfort to the motorist. Methods of reducing the objectionable noise when this technique is used, were also identified.

Based on WisDOT bid tabulations, cost analysis using the equivalent uniform annual cost method showed that a resurfacing project would cost approximately fourteen times more than milling without crack treatment and approximately ten times more than milling with crack treatment.

Therefore it can be concluded that the fine tooth rut milling technique is a cost effective method of rehabilitating a rutted AC pavement when a short term pavement life performance is adequate to meet the needs.

RECOMMENDATIONS

Available results indicate that fine tooth rut milling is a viable rehabilitation technique for a Portland cement concrete (PCC) pavement with an asphaltic concrete (AC) overlay which has experienced premature rutting over its service life. This technique is therefore recommended for use on these types of pavements when a service life of six years or less is desired. The method however, is not recommended for pavements where the surface layer is = 1.25 inches (31 mm). In addition, it should not be applied to paved shoulder thicknesses = 2.00 inches (50 mm).

Numerous factors effect the performance of highway pavements, some of which were not controlled in this investigation. Hence, caution and judgement must be exercised when deciding on using this technique. Also, the AC overlay where this technique was used was less than ten years old. Although the effect of aging was not studied in this project, caution is needed when applying this method in older, more “brittle” AC overlays.

REFERENCES

1. Boesen Anthony & Eastenson Bruce
   “Fine Tooth Milling Treatment of Rutted Asphalt Concrete Pavements”
   Interim Report, Wisconsin Department of Transportation
   August, 1992

2. Waldschmidt Jay
   “Noise Study for the I-94 Rut Grinding Project”
   Noise Study Report, Wisconsin Department of Transportation
   December, 1991

3. Wisconsin Department of Transportation
   “Pavement Preservation Strategy”
   June, 1997

4. Kuemmel D.A. et al
   “Impacts Related to Pavement Texture Selection”
   Final Report WI/SPR-06-96, Wisconsin Department of Transportation.
   January, 1997